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COMPARISON OF WIRELESS TIME SIGNALS FROM ANNAPOLIS AND LAFAYETTE

BY R. MELDRUM STEWART

OF the many radio time-signals now being sent out by various stations, the only ones (at least of those readily observable at Ottawa) which can lay claim to any high order of accuracy are the ordinary mean time signals from the United States naval stations Annapolis and Arlington, and the "scientific" or "rhythmic" signals from the French stations Lafayette (Bordeaux) and Lyons.

The signals from Annapolis and Arlington, which are identical except for a small difference in correction for relay lag, are sent automatically by the clock of the U. S. Naval Observatory at noon and at 10 p.m., eastern standard time; as a list of the daily corrections and the value of the relay lag is issued every month, these signals, after the corrections have been applied, may be taken as a true record of Greenwich mean time, as determined at Washington, including, of course, a possible constant due to error of longitude, together with variable errors depending on observation and clock-rate.

The rhythmic signals from Lafayette and Lyons are sent by an auxiliary local clock which is rated to gain about half an hour per day, so that, roughly, 50 beats correspond to 49 seconds; they are designed for observation by the method of coincidences with a mean time or sidereal clock; a series consists of 300 beats, of which the 60th, 120th, 180th and 240th are omitted for identifica-

tion. The signals are sent by Lafayette at about 8h G.M.T. and by Lyons at about 20h; the exact instant is, however, not predetermined. The signals are observed at the International Time Bureau, Paris; a list is issued every month giving for each day the exact Greenwich time, as observed at Paris, of the first and last beats of the series; the time of the last beat is also given daily by radio some time subsequent to the actual signals. This, then, with the same limitations as above, may be taken as furnishing a true record of Greenwich time as determined at Paris, and is directly comparable with the results from the Washington signals, and also with time observations made at Ottawa

The reception of the signals at Ottawa is accomplished normally by the method of coincidences by extinction, a method first suggested by W. E. and F. B. Cooke,* which has been found to work excellently in practise, and is probably the most accurate and the most free from personality of any of the coincidence methods. For comparison with mean time signals a chronometer rated to gain about 15 minutes per day is employed, coincidences occurring at intervals of approximately 100 seconds; for the rhythmic signals either the same or a sidereal or mean time chronometer may be used. The probable error of a complete comparison under good conditions has been shown to be less than .005 sec., including the error of comparison between the observing chronometer and the standard sidereal clock. Occasionally chronographic records of the signals from both Annapolis and Lafayette have also been employed.

Emission of signals by Lafayette was begun in April 1921; since then they have been received at Ottawa whenever possible. It may be remarked that during the autumn and winter months the signals have been invariably strong and clear; in the summer, however, interference by atmospheric disturbances ("static") was quite serious—so much so that during July the receipt of the signals was the exception rather than the rule.

In the accompanying table are given the mean results of the comparisons for each month in 1921, beginning with April, together with the general means. Only those dates have been included on which signals from both Annapolis and Lafayette were received;

M. N., 77, p. 469 (March 1917).

COMPARISON OF WIRELESS TIME SIGNALS

1921 Month	$O-W$	$O-P$	$P-W$	No. of comparisons
	s	s	s	
April	.052	.067	−.014	9
May	−.004	.000	−.004	19
June	−.068	−.013	−.055	16
July	−.067	.210	−.277	3
August	−.042	−.043	.001	18
September	−.051	−.108	.057	14
October	.022	−.036	.058	24
November	−.027	−.074	.047	26
December	.029	.022	.007	21
Weighted means	−.013	−.024	.011	150
Transmission time	.002	.019	.017	
	s	s	s	
Difference of time	−.015	−.043	.028	

the comparisons between these stations (column 3) are therefore practically independent of Ottawa time observations and clock-rate, and are presumably substantially the same as would have been obtained by direct comparison; the comparisons between each pair of observatories are therefore practically on the same basis. The individual results for Annapolis have been corrected for the announced errors of the Washington clock and for the lag of Annapolis (.08 sec.); the Paris times are, however, based on preliminary extrapolated values of the clock correction; while this fact would increase the apparent probable error of the French signals the effect on the mean would presumbaly be small.

The most striking fact in this comparison is the presence of comparatively large systematic effects extending over considerable periods. It is shown fairly clearly from the monthly means, but is much more evident on an even cursory examination of the individual results; the differences occur frequently, in all three cases, in "runs" extending from a few days to several weeks or longer. Evidence of this is also present in the deduced probable errors.

The probable error of a single comparison may be deduced by the formula

$$r = .6745\sqrt{\frac{[V^2]}{N-1}}$$

where the V's are the residuals of the individual quantities from the mean, N being the whole number of observations. It may also be deduced from the monthly means by the formula

$$r = .6745\sqrt{\frac{[pv^2]}{n-1}}$$

where the v's are the residuals of the monthly means from the general mean, the p's the weights of the monthly means and n the number of months. These two values of the probable error should, in the absence of systematic effects, agree within fairly small limits; their actual computed values are as follows—

	$O-W$	$O-P$	$P-W$
	s	s	s
From individual comparisons	±.038	±.072	±.065
From monthly means	±.105	±.162	±.159

The deduction to be drawn from the marked discordance of the two sets of probable errors is of course that there are present in the individual results systematic discordances which vary from time to time. Since the probable error of reception amounts to only a few thousandths of a second these irregularities must presumably originate in the observed values of clock correction at the three observatories concerned. The cause of such errors is obscure, and its elucidation will probably present serious difficulties; it is, however, a question which must be faced, and its solution, if attained, will be a considerable step forward in the science of meridian astronomy.

The differences in the final line of the table are to be taken as representing the errors in the assumed longitudes of the observatories, complicated by whatever systematic errors, constant or variable, are present in the observations. In the light of what precedes, however, they must be taken with reserve, since their probable errors, on account of the variable systematic effects, appear to be of the order of one or two hundredths of a second.

Dominion Observatory
Ottawa, February 1922.

CHRONOGRAPHIC RECORDING OF WIRELESS TIME SIGNALS

By R. Meldrum Stewart and J. P. Henderson

PRACTICALLY all modern wireless telegraph receivers in use to-day employ the three electrode valve not only for detection but also for amplification. With various types of these, work has been carried on at the Dominion Observatory in receiving time signals from both U.S. and European stations and making daily comparisons with our own primary time service.

From spark transmitting stations the actual audio frequency of the spark is received, but from continuous wave stations a beat note of suitable pitch is obtained by either the self heterodyne or separate heterodyne method. Either the original audio frequency, radio frequency, or an inter-radio-audio frequency beat note, or the pure audio frequency beat note or any combination of these is amplified by suitable circuits till sufficient intensity is obtained. Annapolis and other continuous wave stations are preferable to the audio frequency spark stations for time transmissions, as in the former the signal may be assumed to begin instantly (or the lag is of the order of the radio frequency only) the transmitting relay operates, whereas Arlington and other spark stations may be assumed not to transmit until the first spark after the relays close—i.e., on an average a lag of one half the time between sparks. Actual comparison between imitated audio frequency spark (about 600 per sec.) and c.-w. signals from another aerial showed the advantage in rapidity of answer of the recording relays in favour of the c.-w. signals to be of the order of 0.004 sec.

The method of comparing the local clock with the wireless time signal that has been most generally employed here has been an ear coincidence method utilizing a gaining chronometer whose contact points open every second a relay which is placed in the aerial circuit of the wireless receiver in such a way that during

the first half of each second as read on the chronometer no signal can come through to the observer's ears. As these "opens" are constantly sliding forward on a received mean time signal they begin obliterating the signal from the last part of it first, then creeping up till finally all is lost—this moment, or a shade later, being taken as the moment of coincidence or the moment when the beginning of a second of the "vernier" scale chronometer exactly coincides with the beginning of the mean time wireless signal. If Lafayette, France, be used, who sends time dots gaining about 1 sec. in every 46 of mean time, the same chronometer (in our case this is rated to gain about 1 sec. in every 97 sec. on mean time) may be used but as the time vernier scale is now running the opposite direction, as it were, the first appearance of the signal from obscurity behind the "opens" of the local relay is noted. In each case of course, reading of coincidence is made on the chronometer for convenience, as well as the approximate reading of it when the "reference" omitted dots of the transmitting station occur—this latter to give clue to the dot corresponding to the reading of the chronometer when the coincidence was noted.

A method somewhat to be preferred would be one by which the actual signal would be recorded on a chronograph along with the primary clock, this giving an automatic record which could be used at any time in the future for reference and check, besides eliminating all possible chances of personal equation.

The matter of securing a record of a strong transmitting station not too far distant is not difficult when static is not too severe, but to secure also a record of the local clock that will be comparable with the outside signal is a serious matter as either both the signal and the clock must come through without lag (which is practically impossible when ordinary telegraph relays are used) or else the lags must be the same or their difference known and must remain constant when different stations and different strengths of signals are used.

Records on phonograph waxed cylinder though conveniently made are by present methods almost undecipherable by eye and hence unsuited for scaling. Some sort of pen record is obviously most to be desired, as this would be immediately available, in this way being preferable to a phonographic record.

The radio signal is received and amplified up in the usual manner, one to four or more bulbs being used depending on the initial strength of signal and the sensitivity of the relay which is to work through either directly or indirectly to the chronograph. Three choices of method of operation at the last bulb of the series (if an alternating E. M. F. is being applied to its grid by means of the signal) may be made owing to its grid voltage and plate current curve. (a) It may be worked at or near the "kink" at the top of its characteristic curve (grid most positive) where a variation in grid potential produces essentially a decrease in the direct component of the plate current, this being used to open the sensitive relay. (b) It may be worked near the middle of the sloping part of this curve when a symmetrical alternating current is superimposed on the direct component of the plate current—this may then be sent through a transformer with suitable ratio of turns and if an ordinary relay is used the induced current from the secondary of the transformer may be rectified by a Tungar or other rectifier bulb. (c) It may be operated near the lower "kink" of its characteristic curve (grid more negative normal than in a or b) when an A. C. potential or signal on the grid effectively produces a D. C. increase in plate current. The shape of the characteristic curve (grid pot.—plate current) of the bulb itself naturally determines the most suitable place to work, but in general all the bulbs on the market can with comparative ease be made to work satisfactorily in any of the above three methods. It has been found that the use of a grid condenser, condenser with high resistance shunt across it, or even the high resistance (of the order of a megohm) in series next the grid also aids in obtaining large change in plate current for relay operation, the improved action being probably due to amplification or its equivalent being obtained in addition from the preceding bulb by means of both resistance and capacity coupling as well as by the audio-frequency inter-valve transformer.

The relay chosen should preferably have a very small time constant, the moving parts should be of very small mass, it should operate on a small expenditure of energy, and it should be designed so that its lag will be practically constant irrespective of the strength of signals. As the relay naturally has to leave one stop (or con-

tact) before it can reach the other it is preferable to place it in the circuit so that its contacts are normally closed, the wireless signal causing it to open its contacts and record on the chronograph either directly or through another heavier duty relay.

Various methods have been suggested for introducing the local clock. Relays on opening generally produce a slight spark, accompanied by radio frequency waves resulting from the inductance and capacity in circuit; this may be introduced as a "click" into the receiving set. Results seemed to show the click method unsuitable as its operating time depended too largely on the strength of the clicks; lags varying from $0.^{s}006$ to $0.^{s}03$ were obtained with different relays and strengths of clicks. The local clock may operate a buzzer which will then act as a miniature transmitting set operating either directly into the aerial or by inductive coupling to the tuning coils of the receiving set. In this case there will be less time lost before the signal comes in if the buzzer is left to sing continuously and the clock relay by its "opening" merely "opens" a short on the active coupling coil connected with the buzzer. With a buzzer that was operating at a frequency of about 400 cycles per sec. actual results showed an advantage of about $0.^{s}005$ for the latter method.

The load imposed on the rest of the circuits by the tuned aerial when using the buzzer either radio or audio frequency inductively coupled was found not to be material—results agreeing within $0.^{s}001$, whether aerial was connected or not.

For absolute similarity of clock and radio signals the clock may cause another local transmitting set to send, say on a nearby aerial, a c.-w. signal of approximately the same wave-length, these waves being received and heterodyned in exactly the same way as the waves of the distant station, and hence without different time lag. Again the clock may simply change the value of the plate current in the last bulb in exactly the same way as the outside signal, hence operating the relay and recording similarly; actual tests of this which is the simplest of all, appeared to show that the results were the same as with the outside signal within the limits of error, or $0.^{s}001$.

Relays used included, besides ordinary and special telegraph types, a Marconi 10,000 ohm such as designed for the old coherer

receivers, a Weston 500 ohm special wireless relay, and a Baldwin 'phone having a tungsten contact mounted on its diaphragm. When ordinary 150 and 300 ohm telegraph relays were used a Tungar bulb was connected to rectify the A. C. output of a suitable transformer secondary. The specially reconstructed 'phone gives very consistent satisfactory results, its time lag appears to be of the order of a thousandth of a second and is not dependent on the strength of signals. It can be used to open the circuit to the next relay, an ordinary 300 ohm telegraph relay either by a D. C. component change of the plate current flowing through its coils of the order of 50 micro-amperes or by operating on the A. C. component when it opens and closes its contact circuit alternately with the frequency of the incoming signal.

A pen may be mounted directly by a connecting mechanism to the diaphragm of a Baldwin telephone receiver and made to write on the chronograph sheet. If a recorder lighter and quicker to respond is required, the pen may be replaced by a fine light steel point which can trace a line on smoked paper. This gives a convenient means of obtaining an actual true record of the signals without time lag greater than a fraction of the natural period of the telephone diaphragm and its attachments, which may be easily made of the order of a few thousandths of a second. By this means records were made, scalings of the sheets showing comparisons of the wireless signal with various methods of introducing the local clock in the following ways: (1) the ear coincidence method, (2) these same coincidences as recorded on the smoked paper; (3) clicks induced in aerial recorded on the sheet; (4) "opens" in the aerial, when the clock relay actually opened the aerial and obliterated the outside signal on the smoked paper; (5) buzzer signals, a wavy line or a broadening of the sharp fine line on the sheet (buzzer operating continuously or non-continuously) (6) continuous wave signals as sent by another local transmitter and recorded similarly to the buzzer signals except that the record is more uniform due to the purer audio notes used. All these being compared with the results obtained in the same set of observations using a relay to record either on the printing chronograph or on another drum chronograph.

(1) and (2) give similar results showing there to be essentially

no personal error greater than a few thousandths at most, these correspond well with (5) the buzzer scalings. (3) though unsuitable for recording through the relays as the lag varied up to 0.02s. depending on the strengths of the induced clicks and the type of relay used, yet fairly consistent results were obtained with the telephone relay showing apparent lag intermediate between the above and (4) the "opens" in the aerial which latter corresponded with results obtained by the relays recording directly. If all results are grouped together to bring out the difference between the results of the relays as against the other methods (those agreeing with the coincidence results) it would appear that systematic differences occur of the order of 1/100 sec., the amount of the difference apparently depending to some extent on the arrangements utilized.

When the time comes that the wireless equipment necesasry for recording can be so condensed that it will be sufficiently portable and when the local clock can also be introduced with negligible or always constant lag then we will be able to have permanent records of time comparisons for longitude, gravity or other field determinations; also the watchmaker will have visible records of the performance of his timepieces. It should be mentioned that the astronomer himself as well as the navigator uses these wireless time signals—in many observatories there are no longer tedious hours spent at a meridian circle merely in order to obtain time for local use—this is now relegated to the larger observatories where it can be done so much more accurately and where it is a by-product of other scientific investigations—wireless being the medium of distribution.

Dominion Observatory,
January 25, 1922.

TWO SPECTROSCOPIC BINARY ORBITS

By W. E. Harper

THE star ι Trianguli or Boss 497 (R.A., 2h. 06.6m.; Decl., +29° 50′) is a visual double whose separation is about 3″.5.

The brighter star only is listed in the Henry Draper Catalogue as of G0-type and of visual magnitude 5.20. This magnitude probably refers to the combined brightness as the star appears fainter than 5.2. There is over a magnitude difference between the components, and probably assigned magnitudes of 5.5 and 6.7, which would give a combined magnitude of 5.2, would be about right. The star is number 1137 in Burnham's General Catalogue where the statement is made that the components are relatively fixed but have a common proper motion of 0″.10 per year.

Only the brighter star of the pair appeared on the writer's program for radial velocity determination, but when it was discovered from the first plate in 1919 to be a spectroscopic binary it was decided to have measures of the fainter star also. The result has been that both stars have proved to be spectroscopic binaries with the further interesting feature that in each case the spectrum of each component is recorded on the plates.

The Brighter Star.—Twenty-seven plates were used in the determination of the orbit of the brighter star. Four of these showed the lines as single, two occuring at each crossing point of the curve. On the remaining twenty-three both spectra were measured and thus the orbit is based upon the equivalent of fifty plates. The plates were made with the single-prism spectrograph in general use, whose dispersion at λ 4200, the central region, is 25.7 A per mm. Seed 30 plates were used throughout.

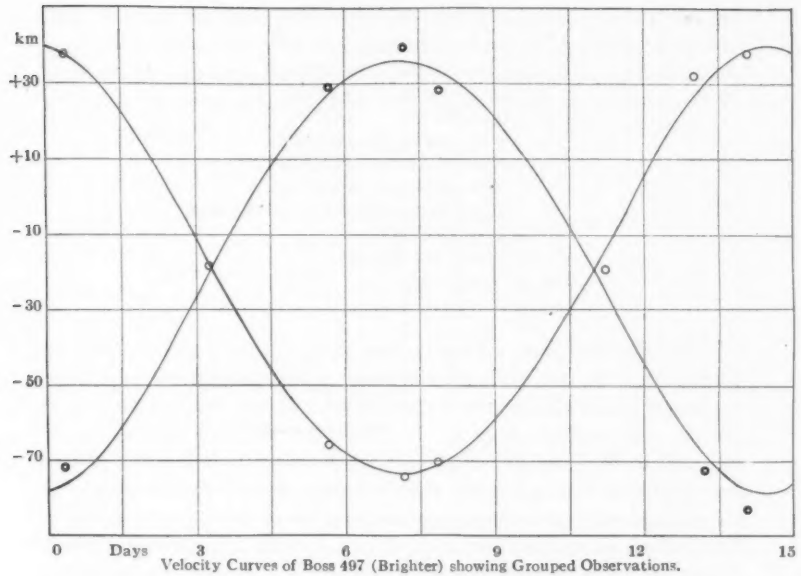
The spectra were measured sometimes with the Hartmann comparator, sometimes with the micrometer engine and frequently with both, the mean result being used. The lines are sharp enough for the comparator but as the semi-amplitude of the range in velocity for either component is less than 57 km the consequent close doubling of the lines on most of the plates seemed most

satisfactorily dealt with by the bisection of the individual lines with the micrometer wire. As there is, thus, a goodly portion of the curve where the component lines are partially blended and confused one may be considered fortunate to have obtained the period and other elements from single prism spectra.

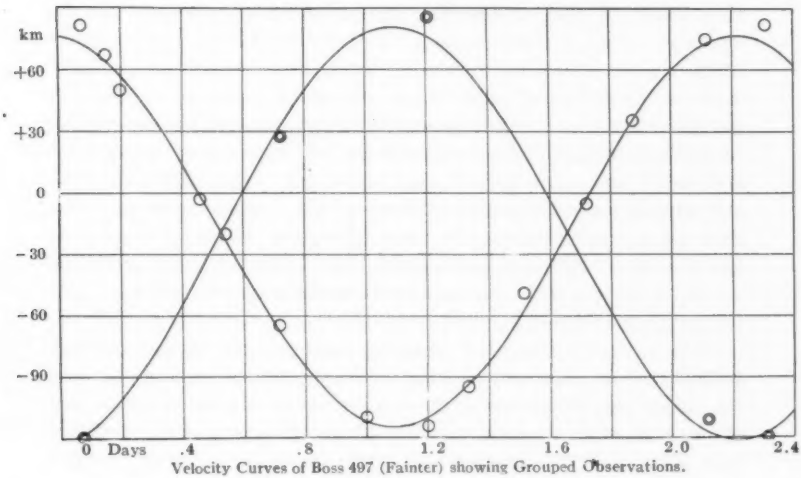
While the spectra are in general alike yet the one whose semi-amplitude is slightly larger and has been designated component II has absorption lines on the average twenty per cent. fainter than the other. Some lines are of about equal intensity, as for example the iron line at λ 4005, whereas in others the ratio appears to be about as 5 to 3. Where such doubling occurs and the continuous spectrum due to one star is superposed on absorption from the other star, too much stress need not be placed on relative differences in the strengths of the component lines. A study of the line intensities in this star in connection with the determination of its spectroscopic parallax, however, makes one wish that spectra having much greater dispersion were available. While the elements of the orbit, here determined, are felt to be fairly accurate yet it would be a valuable piece of work to use three-prism dispersion for securing the plates, not so much to improve the orbital elements as to study in detail the character of the lines due to each component. As stated above, it is only over a portion of the curve that the lines are clearly resolved and that only at the violet end of the spectrum, and one has to be very careful in not making use of any lines whose positions or intensities could possibly be vitiated by neighbouring lines. This is exceedingly difficult in single-prism spectra of solar type.

The period determined from the three years' observations is 14.732 days. The final values of the other elements, as determined from a least-squares solution, are given below.

The solution improved the agreement considerably, the sum of the squares of the residuals for the normal places being reduced from 346.5 to 243.2 or about 30 per cent. The accompanying curve represents the final elements, the observations as grouped being shown and the components being distinguished by means of the double circles representing component II. The probable error of a plate is, in the case of component I, ± 2.5 km per sec. while for component II it is ± 4.3 km per sec.



Velocity Curves of Boss 497 (Brighter) showing Grouped Observations.



Velocity Curves of Boss 497 (Fainter) showing Grouped Observations.

FINAL ELEMENTS

P = 14.732 days
e = .043 ± .002
ω_1 = 5.39 ±14°.13
ω_2 = 185°.39 ±14°.13
γ = −19.09 km ±0.81 km
K_1 = 56.53 km ±1.22 km
K_2 = 56.98 km ±1.51 km
T = J.D. 2,422,243.157 ±0.585 days
$a_1 \sin i$ = 11,441,000 km
$a_2 \sin i$ = 11,532,000 km
$m_1 \sin^3 i$ = 1.120 $\odot$
$m_2 \sin^3 i$ = 1.118 $\odot$

The Fainter Star.—Twenty-five plates were used in the determination of the orbit of this star. The equipment used was the same as for the brighter star but the plates were all measured on the micrometer engine. In this star the spectra are quite unequal in the intensity of the absorption lines. When the phases are such that the spectrum shows double lines a casual glance at the plate would give one the notion that there were a score or more lines which could be seen as double. A close comparison of such plates with one where the lines are single, however, soon shows that many of the supposedly double lines can be accounted for as single lines of another wave length. But there still remain, after such a rigid examination, some lines which are genuine doubles, λλ4215 and 4227 being examples. Other lines were glimpsed at the positions they should occupy for component II, and no doubt if fine-grained plates had been used its spectrum would have recorded itself more clearly on the plates. The faintness of the star and the general poor condition of the "winter seeing" made such seem inadvisable at the time. The spectrum of component I has been measured as approximately F2. Such measures are based on our "type curves" which are incomplete as yet but such a value for its type will not be far astray.

The period determined from the three years' observations is 2.2365 days. After preliminary elements had been obtained by the usual graphical method a least-squares solution was put through to improve such values. Unlike the case of the brighter star, where all observations of both components were grouped

into *one* set of observation equations, it was deemed advisable, from the meagreness of the data of component II, to base the solution on the data of component I alone, reserving for a separate solution the semi-amplitude of the velocity (K_2) of component II. The elements follow:

FINAL ELEMENTS

P = 2.2365 days
e = .010 ±0.015
w_1 = 3°.68 ±0°.93
w_2 = 183°.68 ±0°.93
K_1 = 95.43 km ±1.45 km
K_2 = 101.04 km
T = J.D. 2,422,246.698
$a_1 \sin i$ = 2,934,500 km
$a_2 \sin i$ = 3,107,000 km
$m_1 \sin^3 i$ = 0.906 ⊙
$m_2 \sin^3 i$ = 0.855 ⊙

The solution improved the agreement considerably, the sum of the squares of the residuals for the normal places being reduced from 1343.6 to 706.5 or about 47 per cent. The accompanying curve represents the final elements, the observations as grouped being shown and the components being distinguished by means of the double circles representing component II. The probable error of a plate is, in the case of component I, ±3.9 km per sec. The observations for component II are too few in number for the probable error of ±5.6 km per sec. to mean anything.

For some time the author, in conjunction with Dr. R. K. Young, has been engaged upon the problem of determining by the spectroscopic method the parallaxes of all the stars of which this Observatory has taken spectra. With this end in view the spectra of several hundred additional stars, whose parallaxes have been determined trigonometrically, have been secured to calibrate the line intensities with absolute magnitudes. These curves are as yet incomplete, but using preliminary graphs one may hazard a guess as to the absolute magnitudes in the case of both the brighter and fainter stars of this interesting double. Using plates whereon the lines are single in each case the absolute magnitude of the brighter G0 star may be put down provisionally as +3.2 and the fainter F2 star as +3.5 so that they both may be classed among

the brighter dwarfs. If the stars formed a physical system the difference in their absolute magnitudes would of course be the difference in their apparent magnitudes. The difference found is in the right direction but we must wait till fuller data are available. The values suggested for the absolute magnitudes correspond to parallaxes of 0″.035 and 0″.023 for the brighter and fainter stars respectively so that in the rough a mean parallax of 0″ 03 could be ascribed to the double. In addition to the suggestion of a physical system from their common proper motion and distance, our results also show an identity of radial motion, that for component I being −19.1 km and for component II −19.8 km per sec.

If one wished they might speculate on the elements of the double star system, for such it appears to be. The inclination of either spectroscopic orbit is of course unknown and there is thus the uncertain $sin^3 i$ in the mass function. From other considerations we may infer, though, that the combined mass of the two stars is not very greatly different from its minimum value of 4 times the sun. Adopting the preliminary value of the parallax and assuming an average value for the mean separation, we find by applying the harmonic law, a period of about 1600 years. So many unknown factors enter into the situation, however, that such a result should not be looked upon as being in any way definite. The period is no doubt greater than 2000 years or else a change in the relative positions of the stars would have been detected in the interval over which they have been observed.

Dominion Astrophysical Observatory,
Victoria, B.C.

December 31st, 1921.

THE PICKERING SERIES AND BOHR'S ATOM*

By H. H. Plaskett

MANY of the important developments of modern physics have taken their origin in or have been verified by astronomical observations. Such, is for example, the fact in the case of the Pickering series. The lines composing this series were originally found in 1896 by E. C. Pickering in the star ζ Puppis. Rydberg, on the basis of his work on spectral series, assigned the lines to the element hydrogen. Fowler later found the series in the laboratory, and finally Bohr was able succesfully to account for its appearance as a result of his theory of atomic structure. It is the purpose of this article to give some account of these various investigations which had their inception in Pickering's discovery.

1. The 4686 Series

It is possible from the multiplicity of lines which forms the spectrum of an element to select groups of homologous lines. The lines of such groups are characterized by a like appearance (sharp, nebulous or easily self-reversed), and by the same behaviour under varying conditions of excitation, or under the Zeeman effect. In 1890 Rydberg[1] was able to show that the lines in such a group formed a series, the members of which conformed to a relation

$$\nu(=10^8/\lambda)=\nu_\infty-N/(m+\mu)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where ν is the wave-number of a line (reciprocal of wave length in cms.), N a universal constant ($=109{,}677.7$), μ an empirical parameter, and where m takes on integral values 2, 3, 4..., thus giving rise to succeeding members of the series.

Further, in general, Rydberg found that each element showed three types of series. These were: a series of strong lines, the Principal (P) Series; one of sharp lines, the Sharp (S) Series; and one of nebulous lines, the Diffuse (D) Series. Between these three

*Summarized from an address read before the "Victoria Branch of the Engineering Institute of Canada".

series of an element there were certain important relations. (1) The D and S series had a common limit. (2) The difference between the limit of the P series and the common limit of the D and S series gave the first member of the P series. And (3) when m was put equal to unity in the formula for the S series, the first member of the P series was obtained with a negative sign. These relations are shown in figure 1 for the lithium spectrum. The first row shows the brighter lines of lithium. In the second, third and fourth rows the lines are sorted out respectively into the P, S and D series. The abscissae are wave numbers. Relations (1) and (2) given above are immediately evident on reference to the diagram; the third relation is not shown. These inter-series relations may also be put analytically since clearly the limit of the series ν_∞ can be expressed in a form $N/(m+\mu)^2$. This results directly in the following expressions.

$$(2)\quad \begin{cases} \text{P series} & \nu = N\{1/(1+s)^2 - 1/(m+p)^2\} \quad m=1, 2, 3\ldots\ldots \\ \text{S series} & \nu = N\{1/(1+p)^2 - 1/(m+s)^2\} \quad m=2, 3, 4\ldots\ldots \\ \text{D series} & \nu = N\{1/(1+p)^2 - 1/(m+d)^2\} \quad m=2, 3, 4\ldots\ldots \end{cases}$$

It is evident that if the S series of an element is known, the P series may be calculated, and vice versa.

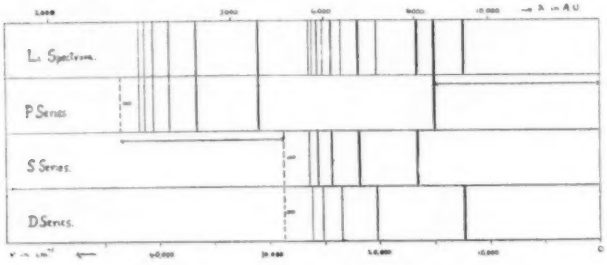


Fig. 1.—Relation between Series in Lithium Spectrum.

Rydberg was able to find series, and series relations such as these, in elements in the first three columns of the periodic system. Further, elements in the same column showed spectroscopically, as well as chemically, progressive similar tendencies. For example the series limits of elements in a column shifted to the red with increase in atomic weight. To the very complete scheme that

Rydberg was thus able to formulate there was one noteworthy exception. This was due to the element hydrogen. From analogy with the spectra of other elements, and from its position in the periodic table it should have shown three series with somewhat similar values of the empirical constant μ to lithium, sodium and potassium. In other words it should have shown a system of series like figure 1. Actually it showed only one very simple series, called the Balmer series, after J. J. Balmer who discovered the formula which represented it, $-\nu = N(1/2^2 - 1/m^2)$.

The discovery in 1896 by E. C. Pickering[2] of the unknown lines λλ5411,4541,4200, etc., in the star ζ Puppis seemed to indicate a way out of this difficulty. In a later note Pickering[3] showed that the new lines could be grouped with the Balmer hydrogen lines in a formula of the type $\nu = N(1/2^2 - 1/m^2)$ where the Balmer lines are given by integral values of m, and the Pickering lines by 5/2, 7/2, 9/2, etc. Kayser[4] deprecated this procedure, and Rydberg[5] followed with a brief but highly important note. He computed series formulae for the Pickering lines and the Balmer series, and showed that both series had a common limit. His formulae may be put in the form

Pickering Series $\nu = N\{1/2^2 - 1/(m+0.500737)^2\}$ $m = 2, 3, 4 \ldots$.
Balmer Series $\nu = N\{1/2^2 - 1/(m+1.00)^2\}$ $m = 2, 3, 4 \ldots$.

By comparison with (2) it is seen that these series are similar to the S and D series of an element. Their proper assignment, Rydberg pointed out, may be made by a comparison of the values of μ. In the second column of the periodic table for the S series $\mu = 0.597337$ (Li), $= 0.649840$ (Na), and for the D series $\mu = 0.998063$ (Li), $= 0.988436$ (Na). From these values and their progression Rydberg was justified in assuming that the Pickering lines formed the S series and the Balmer lines the D series of hydrogen. He could then proceed, as has been previously indicated, to the calculation of the wave-lengths of the members of the P series. As a result he found that the first line should occur at λ4687.88, and succeeding lines at λλ2734.55, 2386.50, 2253.74, 2187.60 which are all below the limit of atmospheric transparency. However, in ζ Puppis itself and in numerous nebulae, there was an excessively bright line with wave length λ4686. There was, therefore, since inter-series relations only hold approximately, ample justification

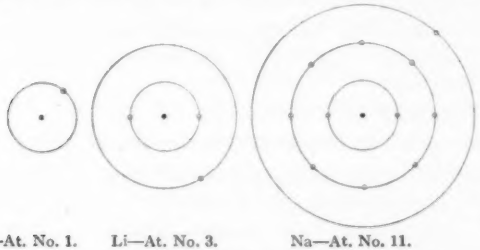
for assuming that the line 4686 was the first number of the P series of hydrogen.

In this identification there was only one flaw. The so called P and S series of hydrogen were never observed in the laboratory. However, in 1912, in a tube containing helium with hydrogen impurity, Prof. A. Fowler[6], who had long been interested in this problem, observed a line flickering near λ4686. With this as a clue Fowler experimented until he found that the line 4686, and the remaining members of the series as predicted by Rydberg, could be produced at will with a sufficiently condensed discharge. At the same time under these conditions there appeared very faintly the Pickering series. In addition, however, there appeared lines at λλ3203.30, 2511.31, 2306.20 which by their behaviour were clearly related to the 4686 and the Pickering series. These new lines Fowler grouped into a "second principal series". In the lack of positive experimental proof, since hydrogen was always present, it was concluded that the 4686 series, the 2nd P series (3203, 2511, etc.), and the Pickering series were due to hydrogen.

2. Bohr's Theory

Shortly after Fowler's discovery of the 4686 series in the laboratory, Dr. N. Bohr[7] announced the preliminary results of his theory of atomic structure. His problem was to determine from the characteristic line spectrum of an element the structure and dynamics of the atoms of that element. Certain fundamentals of atomic structure had already been made clear. A long series of experiments, initiated by J. J. Thomson's work on the discharge of electricity through gases, had shown that there was, common to all elements, certain minute carriers of unit charges of negative electricity. These were called *electrons*. The charge carried by an electron is 4.77×10^{-10} electrostatic units, the electron diameter is of the order of 1.8×10^{-13} cms. and its mass is approximately 1/2000 of the mass of the hydrogen atom. From their universal occurrence such electrons must be a standard part of all atoms. Two questions then arise: (1) how many electrons are there in the atoms of the various elements, and (2) since the atom as a whole is electrically neutral, what is the nature of its positive part? The experiments of Barkla, Crowther and Sir E. Rutherford

were decisive in showing that the number of electrons in an atom is approximately one-half the atomic weight of the element; and also in showing that the positive part of the atom and almost its entire mass are centred in a minute positive *nucleus*, of diameter less than 1/100,000 of the diameter of the atom. Our resulting knowledge of atomic structure is shown schematically in figure 2.



H—At. No. 1. Li—At. No. 3. Na—At. No. 11.

Fig. 2—Illustrations of Atomic Structure.

The number of electrons, and equally the positive charge on the nucleus in terms of the unit charge carried by the electron, is given by the *atomic number* (which is approximately ½ the atomic weight) of the element (*i.e.*, by the ordinal number of the element in a list of the elements in order of increasing atomic weight). Thus hydrogen has 1 electron since its atomic number is 1, lithium 3 electrons since its atomic number is 3, sodium has 11 electrons since its atomic number is 11, and so on. The electron arrangement in the diagram is that of the Lewis-Langmuir theory, save that in sodium the eight electrons in the second ring are actually at the corners of a cube.

Bohr selected the hydrogen atom consisting of a nucleus with a single revolving electron as the simplest to attack. The problem for solution was how such an atom emitted the characteristic hydrogen spectrum consisting of the Balmer series, and, presumably from Rydberg's theory and Fowler's investigation, the Pickering, the 4686 and the second principal series. According to classical dynamics the electron could revolve about the nucleus in any one of an infinite number of orbits. On the basis of Planck's quantum theory, which requires an electron to radiate energy in discrete quanta of the size $\epsilon = h\nu$ ergs where ϵ is the size of the

quantum, $h(=6.55\times10^{-27}$ erg-seconds) is Planck's constant and ν is the frequency of the emitted radiation, Bohr fixed certain of these infinity of possible orbits. His first assumption was that an electron could revolve only in those orbits in which the angular momentum of the electron $m_0\omega a^2$ was equal to $nh/2\pi$, where m_0 is the electron mass, ω its angular velocity, a the radius of its orbit, h is Planck's constant and n takes on integral values 1, 2, 3. . . . From this it immediately follows, using the ordinary condition for circular motion, $eE/a^2=m_0\omega a^2$ that the diameters of these possible orbits are given by

$$2a=n^2h^2/2\pi^2m_0eE. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where E is the nucleus charge and e the charge on the electron. For the normal hydrogen atom $n=1$ (potential energy a minimum), and $E=e$, we find inserting the necessary numerical values that $2a=1.1\times10^{-8}$ cms., a quantity of the right order of magnitude. Other possible orbits have diameters 4, 9, 16 . . . times this as n takes on the successive integral values 2, 3, 4. . . . The radii of the possible orbits are shown on a correct relative scale in figure 3.

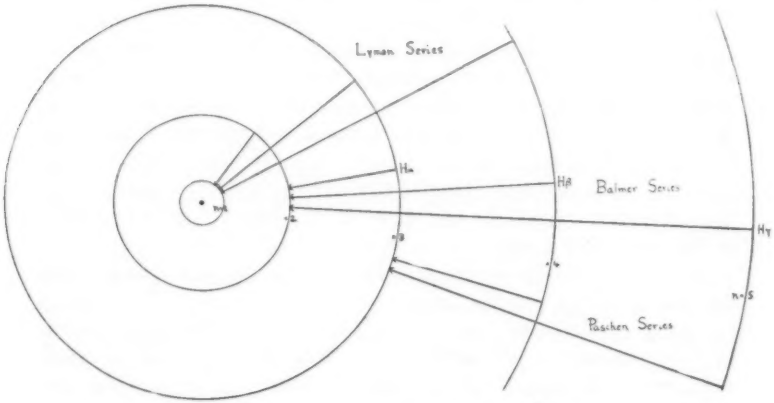


Fig. 3.—Relative Radii of Orbits of Hydrogen Electron.

The system considered has certain definite amounts of negative energy in each one of these stationary possible orbits. This energy is given by the potential energy of the electron less its kinetic

energy of revolution. In fact it may be readily shown that W, the negative energy for a given orbit defined by the quantum number n, is

$$W = -2\pi^2 m_0 e^2 E^2/n^2 h^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Bohr then considers what will happen, when, for some unspecified reason, the electron skrinks from a stationary orbit m to n, where $m > n$. There will be a certain loss of energy $\Delta W = W_m - W_n$, and this loss of energy (here Bohr makes his second assumption) will appear as monochromatic radiation of frequency given by the quantum relation $\Delta W = h\nu$, from which it follows that

$$\nu = (W_m - W_n)/h = (2\pi^2 m_0 e^2 E^2/h^3)[1/n^2 - 1/m^2] \ldots . (5)$$

Equation (5) embodies the fundamental result of Bohr's theory. Contrary to the classical theory the electron does not radiate while revolving about the nucleus, but radiation only takes place, when the atomic system suffers a loss of energy due to an electron shrinkage from an outer to an inner orbit. This loss of energy then appears as radiation of frequency ν given by equation (5).

Since for hydrogen $E = e$ (5) reduces to the form

$$\nu = (2\pi^2 m_0 e^4/h^3)[1/n^2 - 1/m^2] = N_H[1/n^2 - 1/m^2] \ldots . (6)$$

Inserting the necessary numerical values, $2\pi^2 m_0 e^4/h^3 = 1.09 \times 10^5$ cms.$^{-1}$ whereas from spectroscopic measurements N, the universal constant, $= 1.09678 \times 10^5$. Different series of hydrogen according to Bohr will be given by different values of n, while integral variations of m will produce the various members of any one series. Thus with reference to figure 3, which gives a diagrammatic representation of the Bohr hydrogen atom, a series of lines will be given by atoms in which electrons are falling from outer orbits to the first orbit ($n = 1$). Such a series was found in the ultra-violet spectrum of hydrogen by Lyman. The Balmer series is given by atoms in which electrons are falling from outer orbits to the second ($n = 2$). Finally atoms in which the electrons are falling to the third orbit ($n = 3$) will give a series in the infra-red found by Paschen. But, and this is important, Bohr's hydrogen atom does not emit radiations that will account for the Pickering series or the two principal series found by Fowler.

Bohr next discussed a helium atom which had permanently

lost one electron,—ionized helium. In its outward appearance this helium atom would be similar to the hydrogen atom, as it would consist of a nucleus and a single electron. The difference would lie in the helium nucleus which would have a double positive charge and four times the mass of the hydrogen nucleus. Since the constant is of the form $2\pi^2 m_0 e^2 E^2/h^3$ and for helium $E=2e$, then $N_{He}=4N_H$ for a helium atom with a single electron. With this new constant Bohr showed that all the lines discovered by Fowler, viz. 4686, 3203, 2734, 2511, etc., would fall into a single series of the type $\nu=4N_H(1/3^2-1/m^2)$ where $m=4, 5, 6. \ldots$ The physical interpretation of this formula is that the complete 4686 series is emitted by ionized helium, not hydrogen, atoms in which the single electrons are falling from outer orbits to the third.

The Pickering series, Bohr found, would be given by a formula of the type $\nu=4N_H(1/4^2-1/m^2)$ where $m=5, 6, 7\ldots$ This on his theory means that ionized helium atoms in which electrons are falling from outer orbits to the fourth would give rise to the Pickering lines. But as Bohr pointed out $m=7, 9, 11 \ldots$ gave in this formula the Pickering lines 5411, 4541, 4200, etc., while even values of m gave lines coinciding with the Balmer series. This coincidence is not exact since a refinement of the theory, which takes account of the finite masses of the nuclei and their consequent motion, gives for the ratio N_{He}/N_H not exactly 4 but $4(M_H+m_0)/(M_H+m_0M_H/M_{He})=4.001635$, where M_H is the mass of hydrogen nucleus and $M_{He}=$approx. $4M_H$ is the mass of the helium nucleus. The consequence of this refinement of the Bohr theory is that even values of m in the formula $4.001635N_H(1/4^2-1/m^2)$ will give lines displaced 1 or 2A to the violet of the Balmer lines. In fact Bohr predicts that, in a star or in a vacuum tube containing hydrogen and helium and under proper conditions of excitation, the resulting spectrum will appear as in figure 4. The heavy unbroken lines are the first five members of the Balmer series. The dotted lines are the first ten members of the complete Pickering series, even values of m giving, it will be noted, close companions to the Balmer hydrogen lines. Evidently the discovery of such companions to the Balmer series would furnish the strongest evidence that the Pickering series is due to ionized helium, not hydrogen.

3. Verifications of Bohr's Theory

Since its first enunciation, considerable evidence has accumulated as to the correctness of Bohr's theory. Some of this evidence, taken by itself, is not entirely satisfactory as a verification of the theory. Thus for example, Evans, Stark and Fowler have all observed the line 4686 in vacuum tubes which showed no trace of the hydrogen spectrum. But, as Fowler pointed out, it is not always possible to be sure that hydrogen, occluded in the electrodes or in the walls of the vacuum tube, has not come out when least expected. Subject to no such uncertainty as this, however, are three independent lines of evidence which afford the strongest confirmation of Bohr's theory.

1. The first of these is due to Fowler.[3] By the condensed discharge required for its production, the 4686 series found by him in the laboratory is evidently composed of enhanced lines. As having a possible bearing on the origin of this series, Fowler therefore investigated other enhanced spectra in an endeavor to find series relations. Particularly in the enhanced spectrum of magnesium he was able to get four main series, a Fundamental (containing the doublet 4481), two Subordinate and a Principal Series. These new enhanced series had a Rydberg constant $4N$ like the 4686 series. Further, and this is important, there were no relations between these enhanced series and the ordinary arc series of the element. Accordingly the numerical relations found by Rydberg between the 4686 series which is enhanced, and the Balmer series of hydrogen which is of the arc type, can have no significance. Further, by analogy with the enhanced spectra of magnesium, calcium, barium and strontium, the 4686 series must be a part of the enhanced spectrum of helium. Thus by a method independent of theory, Fowler arrived at a like conclusion with Bohr, namely that the 4686 series was due to helium. This then furnishes a confirmation of Bohr's theory.

2. By virtue of its directness and simplicity, probably the most important verification would be that afforded by the discovery of the Pickering components of the Balmer series (see figure 4). Such a discovery would clearly show, in view of the correction for the motion of the nucleus previously discussed, that the electron and the nucleus, exactly as pictured by Bohr, *revolved* about their

common centre of gravity. The difficulty with this investigation has been in the diffuseness of the Pickering lines, whether observed in the laboratory or in a star.

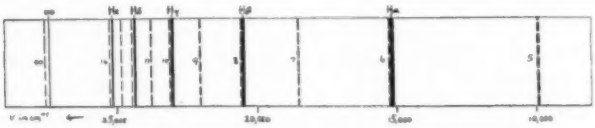


Fig. 4.—Pickering Components of the Balmer Series.

The first attempt was made by E. J. Evans.[9] With low dispersion and long exposures in a highly purified helium tube, he was able to measure lines near the position of the Balmer series. His measured wave lengths indicated blends of the hydrogen lines and the Pickering components, and thus furnished fair evidence of the existence of the predicted components.

The next attempt was a completely successful one by F. Paschen.[10] He used a special form of helium tube with a "hollow box-shaped cathode". Within this cathode, when the tube was operated with a continuous current, there appeared a yellow glow. Examined spectroscopically this glow showed the ordinary helium spectrum, the 4686 series and the Pickering lines. Under these conditions the Pickering lines were comparatively sharp. A trace of hydrogen impurity enabled him, with various orders of a small grating spectrograph, to photograph the Balmer lines and their ionized helium components. His measured wave lengths are given in the table. The first column gives the wave lengths of the Balmer series, the second the wave lengths of the complete Pickering series as computed according to Bohr, and the third column contains Paschen's measured wave lengths. There thus can be no doubt that in the laboratory, Bohr's prediction and consequently his theory, is beautifully verified.

In view of the importance of this verification and for the sake of completeness, it was of interest to examine stellar spectra to determine whether such components existed there. This investigation was undertaken by the writer.[11] A preliminary investigation of O-type stars with low dispersion indicated that 10 Lacertae had lines of sufficient sharpness. In addition J. S. Plaskett pointed out that the Pickering lines in 9 Sogittae were well defined. Using

Balmer Hydrogen Lines	Bohr's Helium Lines		
	Computed	Laboratory	Star
6562.79	6560.15	6560.13	6560.04
	5411.53	5411.55	5411.62
4861.33	4859.35	4859.34	4859.09
	4541.62	4541.61	4541.67
4340.47	4338.70	4338.70	4338.79
	4199.86	4199.86	4200.06
4101.74	4100.00	4100.05	4100.26

two and three prism dispersion, spectra were made of these stars which clearly showed the existence of Bohr's predicted components. In 10 Lacertae components were found to $H\alpha$, $H\beta$, $H\gamma$, $H\delta$, and in 9 Sagittae to $H\gamma$ and suspected for $H\beta$ and $H\delta$. The stellar wave lengths, resulting from measures of many plates, are given in the fourth column of the table. The cases where the observed wave lengths differ from the computed by 0.2A or more, are due chiefly to blends with enhanced nitrogen lines. The evidence from the laboratory and the stars clearly substantiates Bohr's prediction.

3. The final important verification of Bohr's atom is that which takes its origin in a refinement of the theory due to Sommerfeld.[12] So far only circular orbits characterized by the quantum numbers $n=1, 2, 3 \ldots$ have been treated. Elliptical orbits are also of course possible and these orbits Sommerfeld "quantizes" not only with respect to angular momentum, n', but also radial momentum, n'', $n=n'+n''$. He finds that the one quantum orbit may be a circle, the two quantum orbit a circle or an ellipse of eccentricity $\sqrt{3/2}$, the three quantum orbit a circle or ellipses with eccentricities $\sqrt{5/3}$, $\sqrt{8/3}$ and so on. The Balmer-like series are generated as before with frequencies given by

$$\nu = N[1/(n'+n'')^2 - 1/(m'+m'')^2]$$

where the lines are sharp but now depend upon four integers instead of two as formerly. Sommerfeld then considers the relativity correction due to the variation in mass with velocity of the electron. This introduces a correcting term containing the

out that the Pickering lines in 9 Sagittae were well defined. Using factor n'/n''. Thus this term may have different values for the same value of the sum $n'+n''$. The relativity correction therefore requires that the lines be no longer single but have a complex structure. The multiplicity of the ring into which the electron falls determines the main structure of the lines. Thus the Balmer hydrogen lines, generated by an electron falling from outer rings into either the circle or ellipse of the two quantum orbit, are doublets of constant separation. Similarly the 4686 series lines are triplets.

With the "hollow box-shaped cathode" discharge tube already described, Paschen,[10] working in communication with Sommerfeld, examined the structure of the ionized helium lines. He found that the line 4686 and also higher members of the series showed the predicted structure and correct component separations. The structure for hydrogen is much more difficult to determine and is complicated by a Stark effect due to the electrical field of neighbouring atoms. As far as the observations go for hydrogen, they are qualitatively in agreement with Sommerfeld's theory.

Taken collectively, the three chief lines of evidence summarized above furnish the strongest confirmation of Bohr's theory. Each line of evidence taken individually seems to pick out one particular feature of the atomic structure. The Rydberg numbers N and $4N$ confirm the existence of stationary orbits, the existence of enhanced helium components shows that the electron and nucleus revolve about their common centre of gravity, and Sommerfeld's predicted fine structure shows the variation in mass of the electron in its orbit.

Conclusion

The various investigations described in this paper had their origin in the discovery of the Pickering series in ζ Puppis. They have served to establish a far-reaching theory of atomic structure. Incidentally they have shown that the Pickering series in the laboratory and in the stars is due to ionized helium. This typical example of scientific work illustrates the importance of hypothesis which, though not necessarily correct, yet serves to collate groups

of unrelated facts and to direct investigation into new and important channels.

Dominion Astrophysical Observatory,
Victoria, B.C.
January 1922.

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ABSTRACTS OF PAPERS PRESENTED AT THE RECENT JOINT MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AND THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

ERRORS IN MICROMETER MEASUREMENTS

By Ralph E. DeLury

A serious error has been finally traced to capillary action of oil between the nut and screw in certain micrometers,—an action which requires a minute or more to bring about equilibrium in the course of routine measurements of a spectrum line in several adjacent strips of spectrum. In the case of the Toepfer 300 mm. measuring machine employed at Ottawa during the past dozen years, a difference of 0.006 mm has been found between sets of measures of a spectrum line 5 seconds and 150 seconds after the spectrum line was brought beneath the spider thread from a distance of 2 mm (four turns of the thread), to right or left. The rate of settling to equilibrium was more rapid when the screw had been turned out of the nut than into the nut against the pull of the weight. The settling is away from the weight, and may consequently be due to slow return of the oil between thread and nut. This curious effect satisfactorily explains the difference obtained from "left" and "right" measures of the same lines. The mean is not necessarily the true value, since the rate of return to equilibrium is different following turnings into or out of the nut. Differences in the measurements of the same lines by different observers may be due to this cause. Conclusions which have been drawn from such purely differential measurements as those produced by the solar rotation, may be profoundly modified when this error is taken into account. The error may be eliminated by beginning the measurements after equilibrium has been reached, or by using no oil, or by using a lubricant which reaches equilibrium very rapidly or very slowly. In any case the order of the measurements of spectrum lines in adjacent strips of spectrum should be so arranged and repeated that mean values will be freed from this error where it is found to be present.

SECOND NOTE ON CEPHEID VARIATION

By Ralph E. DeLury

A dozen years ago the writer outlined a theory of variable stars, and cepheids in particular, which assumed the action of a satellite to account for the variations in brightness and wavelength. Sometime later in reviewing the theories of cepheid variation, Shapley overlooked this form of the binary theory, pinning his faith on the "pulsation" theory. Recently, Father Hagen pointed out this oversight and advanced a theory similar to mine. Both the convection and pulsation theories assume motions of the gases normal to the star's surface, rising and falling during the period of variation, the former in currents, the latter in an expansion and contraction of the star as a whole. In the present note I wish to point out the possibility of periodic changes of wavelengths due to motions tangentially to the star's surface. It is assumed that in the star there are spots and pores having the characteristics of sunspots in that there is rapid motion (on a much larger scale than in sunspots) from their axes out along the surface of the star, and that as in spots, there is an excess of motion away from the observer (due, as I have suggested in the case of sunspots and presumably of pores as well—to funnel-shaped spots and pores). Greatest wavelengths would coincide with greatest development of the pores, that is lowest brightness of the star, as is the case in cepheids. No change in volume of the star need in this case be assumed.

MERIDIAN CIRCLE OBSERVATIONS ON CIRCUMPOLARS

W. S. McClenahan

It was suspected that in the Meridian Circle work at Ottawa a different value of the azimuth of the instrument was obtained by using Polars at upper and lower culmination. To see if this were true the values of the polar deviation of the instrument (n) were tabulated for as many nights as possible throughout the different years. These results showed that the value of (n) for upper culminating polars was larger than that given by polars

at lower culmination. The values were also investigated to see if there was any magnitude or declination effect but neither was found.

The computations for mean place had to allow for this difference and to see how our results at Ottawa compared with other catalogues the positions of some twenty polars as determined at Ottawa, were compared with Boss's catalogue which is used as standard. The mean difference for the whole gave Ottawa − Boss, − .011 sec δ. The differences for the American Ephemeris show up larger than the Boss differences. One polar differing by over one second of time and others by .5 seconds.

ORBIT OF THE SPECTROCSOPIC BINARY H.R. 5992

By J. W. Campbell

The orbit of this star (1900, R.A. 16h 0.8m, Decl. +8° 22′, vis. mag. 6.1, type A) was determined from 20 plates secured at the Dominion Astrophysical Observatory at Victoria during the past summer. It has a period of 8.855 days, an eccentricity of 0.376 and a mass-function .023 times the sun. The full details of the solution will appear in the *Publications* of the observatory.

THE INFLUENCE OF ASTRONOMY ON MEDICINE

By John B. Fraser

ONE of the chief characteristics of the ancient Greek and Roman was his veneration of the planets, a veneration that ended in worshipping the sun as a god; the moon as a goddess; Jupiter as the father of gods and men; Mars as the god of war; Venus as the goddess of love and beauty; Saturn as the god of time; and Mercury as the messenger of the gods.

Both Greek and Roman looked upon the stars as living spirits which exercised their powers over man from the time of his birth until his death, and which were able to give them public and private revelations regarding future events.

The Egyptians watched the helical rising of the star Sirius closely, believing that it indicated the rising of the Nile river, on

which depended a lean or fat harvest with consequent want or plenty. Sirius was said to be the Mother of Khensu and both were held in reverence by the Egyptians as guarding the health and lives of the people through their influence over the Nile.

During the middle ages the past belief that disease was due to evil spirits or demons, was supplanted by the theory that disease was due to the influence of the Sun, Moon and Stars; and that the constellation under which a man was born governed the type of disease he might expect. Thus if a man was born under the constellation of Aries, the Ram, he might expect headaches, earache, diseases of the eye or ear, meningitis or other brain disease and also diseases or affections of the scalp; but if born under the constellation of Pisces, the fishes, he might expect malformation of the feet, bunions, strains of tendons and joints, etc.; the same rule applied to all the different parts of the body, governed by the different signs of the Zodiac.

By taking a pill and retiring as the evening star appeared, taking a second and rising as the sun appeared, and taking one at midday fasting, this along with the hope inspired by the pill often helped the patient; for all physicians recognize the importance of rest, regular hours and restricted diet.

Readers of Shakespeare's "Macbeth" will remember that when the witches were brewing their charm that one of the ingredients was witches' mummy and to make it more powerful they added "Root of Hemlock digged in the dark", and "slips of yew slivered in the moon's eclipse"; but they may not know that over 80 per cent. of the remaining ingredients used were considered medicines at that time.

The use of such terms as cancer, lunacy, jovial, saturnine, mercurial, martial, etc., show the great influence of astronomy in past centuries.

MEETINGS OF THE SOCIETY

ANNUAL REPORT OF THE VICTORIA CENTRE FOR THE YEAR 1921

(Received too late to publish in the minutes of the Annual General Meeting)

During the year the following lectures were given before the Society:

Feb. 1—"The Romance of Astronomy", by Dr. J. S. Plaskett.
Mar. 8—"Characteristic Features of the Canadian Rockies", by A. O. Wheeler, F.R.G.S.
Apr. 5—"Modern Astronomical Navigation", by Commander B. S. Hartley, R.N.
Apr. 26—"The Northern Lights", by W. E. Harper, M.A.
Nov. 3—"The Dimensions of the Stars", by Dr. J. S. Plaskett.

There are 56 members on the roll now, 13 new members being elected during the year.

Four Executive meetings were held on the dates: January 14th, March 11th, May 12th, and October 6th.

The officers of 1922 elected at the Annual Meeting of February 7th, are as follows

Honorary President, J. S. Plaskett, B.A., D.Sc.
President, W. E. Harper, M.A.
Vice-President, F. C. Green.
Secretary, A. Symonds.
Treasurer, J. P. Hibben.
Council: Mrs. W. B. Christopher; F. Moore; K. M. Chadwick; J. Duff; John Dean; and past presidents F. Napier Denison, A. W. McCurdy, W. S. Drewry and J. E. Umbach.

A. SYMONDS, *Secretary.*

TREASURER'S REPORT FOR 1921

RECEIPTS

Dec. 10, 1920	Balance in bank	$25.71
Dec. 30, 1921	Interest	2.50
	Fees received	122.00
June 15, 1921	Grant from General Council	80.00
		$230.21

EXPENDITURES

May 7, 1921	Fees remitted to General Treasurer	$66.00
	Times Publishing Co.	15.05
	School Board	24.50
	Stamps	2.00
	Balance in bank	122.66
		$230.21

J. P. HIBBEN, *Treasurer.*

Audited and found correct,
K. M. CHADWICK,
Auditor.
February 7th, 1922.

AT VICTORIA

February 7, 1922.—The annual meeting of the Society was held on February 7th, the president, Mr. J. E. Umbach, in the chair.

The following new members were elected: James C. Walters, 440 Gorge Rd., Victoria, B.C.; Mrs. L. E. Pierce, "Roccabella," Blanshard St., Victoria, B.C.; Mrs. R. G. Miller, 2047 Chaucer St., Oak Bay, Victoria, B.C.

The reports of the secretary and treasurer were read and adopted.

The president then addressed the meeting giving a summary of the centre's activity during the past year and offering suggestions with regard to extending the Society's operations. The officers for 1922 were then elected.

The president-elect, W. E. Harper, M.A., then took the chair, and after thanking the Society for the honour conferred upon him, called upon Dr. J. S. Plaskett to address the meeting. Dr. Plaskett gave a lucid and explanatory talk on the use of the "Observer's Handbook".

Dr. R. K. Young replied to the following question which was sent to the secretary:

Q.—About what date and at whose suggestion was the Julian Day introduced? How was the Epoch fixed?

A.—The Julian date was proposed by Joseph Scaliger about the year 1583. In the reckoning of years for the calendar, there are a number of intervals, or cycles, whose recurrence was observed and used by the ancients. These were: the Solar Cycle of 28 years, of which the year A.D. 1 was the 10th year; the Metonic Cycle of 19 years, of which the year 1 was the 2nd year; the Cycle of the Indiction of 15 years, of which the year 1 was the 4th year. The Julian Period is formed from the product $28 \times 19 \times 15$ and equals 7980 years. In the year 4713 B.C. the period began, for that year was the first of each of the cycles. The next cycle begins in the year 3267 A.D. The Julian Day is the number of days that have elapsed since the beginning of the Julian Period.

Mr. H. H. Plaskett, then spoke on the subject, "Series in Star Spectra". He gave an account of the role played by astronomy in one of the most

important developments of modern physical science. Some twenty-five years ago E. C. Pickering discovered in the star Zeta Puppis, some lines of unknown origin. Rydberg, on the basis of series relations, ascribed these lines to the element hydrogen. Fowler later found them in the laboratory in a tube containing helium and hydrogen. Bohr, on the basis of his theory of atomic structure ascribed these lines to ionized helium. Mr. Plaskett then described the work done at the Dominion Astrophysical Observatory which confirmed Bohr's predictions and therefore helped to establish his important theory of atomic structure.

Suitable votes of thanks were heartily accorded by the meeting.

AUGUSTIN SYMONDS, *Secretary.*

AT WINNIPEG

January 11.—The Society met in Room 21, University Arts Bldg., at 8 p.m., the president, Mr. H. B. Allan, occupying the chair.

Mrs. C. H. Kemp, 250 Bell Ave., and Mr. R. Hamilton, 167 Canora St., were elected members.

The president gave a short talk on the value of popular interest and knowledge in astronomy speaking of the pleasure and recreational value, and the intellectual satisfaction, derived from a knowledge of the stars.

The lecture of the evening, entitled "The Romance of Numbers", was given by Prof. F. S. Nowlan. Prof. Nowlan stated that the early development of mathematics was determined in extent and nature by the requirements of astronomy. The number concept precedes the expression of numbers by ordinary speech. There is evidence that our animals, birds and insects have a limited ability to count. Lower savages are known to have no numerical words; others have no words for numbers beyond five, but generally the ability to count by means of fingers or marks, extends beyond the spoken numerals. Counting is always done first on the fingers, among savages, the count beginning on the little finger of the left hand and ending on the little finger of the right. In certain tribes to count above ten, a second man is used, each of whose fingers represent ten, and a third man is used, each of whose fingers represents one hundred, where this is necessary. While most savages count on a basis of 10, because of the use of the fingers as described, some are known that count on a base of 4, others on 12, as well as other bases, while the ancient Phoenicians used 60, which accounts for the use of this number in our systems of time and circular measure.

Numerical symbols were not used for purposes of computation, until after the introduction, of the Arabic system in use to-day. The abacus was used for what computation was done, except by the Arabs, numerals such as the Roman being used only to record results. The Arabic system is distinctive not only in the significance attached to the position of each symbol, but in the use of the zero, which is essential where position has such a significance, and which did not exist in other notations. The zero came into use about 500 A.D., the notation, without the zero, was employed in India as early as 300 B.C. The use of the

symbols was spread by almanacs, institutions of learning having opposed their use. They were first used in the British Isles in 1490, at St. Andrew's Chapter, Scotland. Our system of multiplication was invented in the 17th century, in Florence, Italy. By the end of the 17th century, our number system, including the use of decimals and ordinary operations with numbers was well established. The duodecimal system, in which 12 is used as a base instead of 10, would be more convenient, and Charles XII of Sweden, ordered that it be taught in the schools, but this was never done. Leibnitz suggested the use of a binary system, in which 10 would represent two, 11 three, 100 four, 101 five, 1000 eight and so on. The Arabic decimal system as used to-day, enables children of to-day to perform operations with numbers that only a mathematician among the ancient Greeks could have done, and some would have been impossible.

After expressions of appreciation of the lecture, the meeting adjourned.

C. D. MILLER, *Secretary*.

AT LONDON

February 11.—A meeting was held in the Western University for the purpose of organizing a Centre of the Royal Astronomical Society of Canada, to be known as the London Centre.

The following officers were elected:

President, Prof. H. R. Kingston, M.A., Ph.D.

Vice-President, Miss Grace Blackburn.

Secretary-Treasurer, E. T. White, B.A., D.Paed.

Council: Rev. R. J. Bowen; H. B. Hunter; Mrs. S. R. Moore; J. C. Middleton and W. A. McKenzie.

A Constitution and a set of By-laws were formulated, being in conformity with those of the parent Society.

The following were elected members of the Society: Thos. C. Benson, 856 Wellington St.; Mrs. S. J. Berry, 633 Waterloo St.; Miss S. N. Blackburn, 652 Talbot St.; Miss V. G. Blackburn, 652 Talbot St.; Mrs. W. F. Boughner, 294 Wolfe St.; Rev. R. J. Bowen, 218 St. George St.; Miss A. M. Brown, 133 Kent St.; Major E. L. Caldwell, Wolseley Barracks; Thos. Coleridge, 770 Hellmuth Ave.; Mrs. G. H. Gillespie, 164 Albert St.; Miss M. M. Hamil, 20 Evergreen Ave.; L. W. Hartman, 793 Elias St.; Miss Mary Harvey, 802 Talbot St.; Miss A. E. Henderson, 927 Wellingson St.; Mrs. S. G. Hungerford, 127 Albert St.; H. B. Hunter, 802 Waterloo St.; Miss L. Irwin, 185 Central Ave.; Prof. H. R. Kingston, M.A., Ph.D., 287 Oxford St.; W. A. McKenzie, 10 The Ridgeway; Mrs. J. C. Middleton, 20 The Ridgeway; J. C. Middleton, 20 The Ridgeway; Mrs. S. R. Moore, 201 Cheapside St.; Miss N. Morris, 103 Elmwood Ave.; Dr. W. S. Partridge, 125 Elmwood Ave.; Major Passy, 368 Princess Ave.; Prof. W. J. Patterson, 856 Hellmuth Ave.; E. E. Prince, Wolseley Barracks; Mrs. W. B. Richardson, Grand Ave.; E. T. White, 34 Marley Place; Wm. Wright, 536 Wellington St.; Mrs. W. J. Knox, 244 Hyman St.

March 10.—The Society met in the Western University, the president, Prof. H. R. Kingston, in the chair.

Miss P. Johnston, 812 Maitland St., and Mr. G. H. Gillespie, 164 Albert St. were elected members.

Dr. Kingston gave an interesting and illuminating address on "Other Worlds in our Solar System". By the use of diagrams the relative sizes of the planets were clearly shown, also the orbits of the planets as they move about the sun in the plane of the ecliptic. The lecturer explained the retrograde motion of the planets and with a special piece of apparatus demonstrated the rising and setting of the planets.

With the aid of lantern slides a description was given of many of the interesting facts concerning the planets. Photographs were shown of the rings of Saturn, and the markings on Jupiter and Mars. The phases of Mercury were explained with the help of a slide. The address closed with a study of the sky for March.

E. T. WHITE, *Secretary.*

AT MONTREAL

February 23.—The Society met in the Chemistry Bldg. of McGill University, at 8 p.m., Rev. W. T. B. Crombie, occupying the chair in the absence of the President and Vice-President. Attendance about 25.

The evening was devoted to the answering of questions submitted by the members. The chairman undertook the answering of these questions, which ranged from simple to complex. Some of the questions and their answers briefly stated were:

Q.—In stating the time of sunrise by Standard Time, does the time given refer to the first glimpse of the disc above the horizon, the middle or the last portion? *A.*—The first appearance of the sun's upper limb constitutes sunrise.

Q.—What do the letters L.M.T. and L.A.T. mean in connection with time? *A.*—Local Mean Time and Local Apparent Time.

Q.—Are all stars of the same magnitude, of the same brightness? *A.*—Yes, under modern classification; no, under old classification.

Q.—What is the explanation of variable stars? *A.*—There are various explanations. The variation in the brightness of Algol and many other short-period variables is due to the regular interposition of one body before another. For long-period variables no very satisfactory explanation has been suggested.

Q.—On page 55 of the Handbook the axial rotation of Mercury and Venus is given as 88 and 225 days respectively. Is this not an error? *A.*—No.

Q.—What diameter or power of telescope is sufficient to reveal the four largest of Jupiter's moons? *A.*—One-inch telescope ample.

Q.—What is the height of the Lunar Apennines? *A.*—About 15,000 feet.

Q.—Explain the loop in the path of Mars as given in the Handbook. (Answer was given on the blackboard by means of charts.)

Q.—Are there any limitations to space? *A.*—Metaphysically speaking, space is endless; physically, it is relative.

The answers, so briefly stated above, were given with full explanations by Mr. Crombie. Mr. Crombie also showed a number of lantern slides, some of

which had been received from J. S. Plaskett, D.Sc. Those received from Dr. Plaskett included photographs taken by the Dominion Astrophysical Observatory, of various nebulae.

Mr. Geo. Sample related several instances of astronomers being called into court to give testimony. In one case in Omaha, the fixing by an astronomer of the hour and minute at which a photograph was taken, as evidenced by the shadow shown in the photograph, was proven, and prevailed against the testimony of sworn witnesses.*

Upon motion of A. W. Strong, a vote of thanks was passed to Dr. Plaskett for his gift of slides.

H. E. MARKHAM, *Recorder.*

*See this JOURNAL, vol. 7, 1913, page 88—*Editor.*

AT OTTAWA

February 24.—A lecture on Astronomical Photography was given by Dr. F. Henroteau of the Dominion Observatory, in the Victoria Memorial Museum on February 24th, at 8 p.m.

The lecturer described briefly the larger instruments of the more important observatories, the work they are used in, and the general conditions under which astronomers work. Photographs were shown of the Yerkes, Lick and Mt. Wilson telescopes. It was pointed out that by the use of the photographic plate many objects much fainter than the eye can ever hope to see are permanently recorded. By means of photographs, star counts have been made, and estimates have been made which seem to fix the number of stars between 1,000 millions and 2,000 millions.

The great value of photography to astronomy was plainly brought out by photographs of comets and planets. Many such objects have been discovered by its use. A striking example of this was the discovery of the ninth satellite of Jupiter. This extremely faint object was found on a photographic plate after many hours of exposure. The point of special interest is that the satellite has a retrograde motion. The explanation put forth was that the satellite is in reality a comet, which by chance happened to come too close to the planet Jupiter and was captured. It may be held a prisoner for many decades, and it is possible that its orbit around Jupiter may gradually become larger, and as time goes on, some day Jupiter's attraction may so weaken that it will move off into space again. The rapid motion of some of the small planets, Vesta for example, was clearly shown by a series of photographs. Several interesting photographs of comets were shown, demonstrating at a glance the difference in motion between these objects and the stars.

The various kinds of nebulae were referred to, such as the Orion, a great cloud nebula, and the spiral nebulae. The lecturer gave estimates of the dimensions of these objects, also their probable temperatures. The vastness of these celestial objects is beyond the comprehension of the human mind. It is of interest to the astronomer to calculate and speculate on these great problems of astronomy.

The astrophysical side of astronomy was referred to briefly. From a careful study of the spectra the physical constitution of the stars is studied. The spectrum tells what elements are found in their surface envelopes and also gives an idea of stellar temperatures and how they vary with different types of stars.

R. J. McDIARMID, *Secretary.*

AT TORONTO

February 23.—The Society met in the Physics Building of the University at 8.15 p.m., Prof. C. A. Chant, in the chair.

The chairman explained the nature of the special course of lectures on Meteorology, and then called upon Sir Frederic Stupart, the Director of the Meteorological Service to address the Society upon the subject of "Weather—and How to Forcast It".

In his introductory remarks the lecturer stated that there was no science about which the general public knew so little, and concerning which there were so many superstitions. A knowledge of the coming weather is of the greatest importance to certain classes of people, such as, navigators, travellers, merchants and farmers; and indeed, there are few people to whom a knowledge of how to forcast the weather would not be of value.

Sir Frederic then discussed the causes of the seasons, and explained the various factors determining the climate of a locality, chief of which are: the latitude of the place, the altitude, and the geographical position with respect to land and sea areas. He then described the system of atmospheric circulation, dealing with the origin of the Trade Winds, their velocities, courses and effects; and showing that the distribution of atmospheric pressure over the surface of the earth is not uniform, but that a barometric gradient exists over the middle latitudes.

A number of slides showing the Weather Map of the Meteorological Service for successive days illustrated the movements of Cyclonic Areas, or Areas of Low Pressure, in which the wind blows spirally inward. The changes in the weather of a locality over which a low area passes were described at considerable length and it was made quite evident that the forecaster often has great difficulty in estimating the resulting effects of the more or less complicated conditions.

The lecturer also showed a series of Weather Maps explaining the weather at Washington, D.C., on January 30th, 1922, when the theatre disaster occurred; and also the very unpleasant weather we experienced during the past week when the city's car lines were tied up.

In conclusion, Sir Frederic described briefly the work of the Meteorological Office on Bloor St. where the Weather Map is issued daily, the forecast being made from telegraphic reports from 46 stations throughout Canada. There are nearly 800 stations in Canada observing the daily maximum and minimum temperatures, the rainfall and sunshine, from whose monthly reports statistical records of the climate of Canada are compiled.

March 2.—The Society met in the Physics Building of the University at 8.15 p.m., the president in the chair.

The following were elected members: P. G. Stratton, Superior, Wisconsin, U.S.A.; J. W. Melson, B.A.Sc., 69 Walmsley Blvd., Toronto, Ont.; Wm. H. Woods, 93 Victoria St., Walkerville, Ont.; J. M. Webster, 315 North Fourth Street, Reading, Pa., U.S.A.

The president, then called upon Mr. John Patterson, M.A., F.R.S.C., the Physicist of the Meteorological Service, to give the second lecture of the course on Meteorology; the subjects for the evening being: "The Upper Air" and "Earthquakes".

The lecturer pointed out that at first the directions and velocities of winds, as well as the temperatures of the air, were necessarily taken at the surface of the earth, *i.e.*, at the bottom of the sea of atmosphere, and that from these observations deductions were made as to the probable conditions existing in the upper air. The first attempt to determine the temperature and pressure above the earth were made by man-carrying balloons. In 1862, an Englishman, J. Glaisher reached an altitude of 6.6 miles, which was not surpassed for forty years. Now, however, aeroplanes are able to climb nearly to this height.

Scientists, in order to sound the upper air, do not send up balloons or planes, but use instead, kites and "sounding balloons", which carry up recording instruments. By these means 85% of the atmosphere has been explored, definite information being obtained about the various strata of the air to an altitude of 22 miles. The meteorograph was exhibited and experiments conducted to show how it records differences of temperature and pressure. The results of recent investigations indicate that at an altitude of 6 miles, the temperature remains constant as the height increases. In the troposphere, the first 6 miles of air, in which the clouds occur, the temperature falls off as the height increases, but above this height, in the region of the stratosphere, no clouds exist, and the temperature is constant. Noctilucent clouds, auroral displays and shooting stars occur in this higher region.

The method of sending up Pilot Balloons to obtain the velocity and direction of the wind to heights of 10 miles was described, and a demonstration given of the filling of the balloon with hydrogen, and the way in which a flight is made.

The second part of the lecture was devoted to the subject of earthquakes. A model of a seismograph was exhibited and its operation explained. A good number of slides were shown illustrating the effects of earthquakes, chiefly in India, where the lecturer spent some years during which time he experienced two quakes.

J. A. Pearce, *Recorder.*

NOTES FROM THE METEOROLOGICAL SERVICE

February, 1922

Temperature

The temperature was above the average over the greater portion of Ontario and in Western Quebec and below elsewhere. The negative departure was very marked again in British Columbia, varying from four degrees on the coast to ten and eleven degrees in the Interior. In Alberta and Saskatchewan it was also marked, varying from nine to eleven degrees in the former and from four to seven degrees in the latter Province. In Eastern Quebec and the Maritime Provinces it was from two to five degrees. In Ontario the positive departure was from two to five degrees.

Precipitation

The precipitation was above the average in nearly all portions of Ontario and in Northern British Columbia, also locally in the Western Provinces, elsewhere in the Dominion it was below the average. The departures from average were as a rule much less than an inch, a few exceptions were an excess of 2.20 inches at Barkerville, B.C., and 1.20 inches at Haileybury, Ont., and deficits of 2.30 inches at Vancouver, 1.60 at Victoria and 1.30 inches at Port Dover, Ont.

SEISMOLOGICAL NOTES FOR FEBRUARY 1922

Toronto recorded five disturbances and Victoria six, during the month. The largest was on the 16th, the Toronto trace amplitude showing 1.2 mm. The origin of this earthquake was possibly in Nicaragua. We failed to record the first phase, but the second was recorded at 3h 28m 00s, G.M.T., and the maximum at 3h 40m 24s. The Victoria instrument was not working satisfactorily during this earthquake.

J. Y.

TEMPERATURES FOR MONTH OF FEBRUARY 1922.

STATIONS	FEBRUARY Highest	Lowest
Yukon		
Dawson	6	—52
British Columbia		
Atlin	32	—32
Agassiz	52	35
Barkerville	35	—23
Kamloops	43	—11
New Westminster	47	21
Prince Rupert	46	8
Vancouver	47	20
Victoria	52	25
West Provinces		
Battleford	25	—35
Calgary	46	—26
Edmonton	44	—32
Medicine Hat	42	—30
Minnedosa	18	—28
Moosejaw	25	—36
Oakbank	22	—35
Portage la Prairie	..	..
Prince Albert	20	—32
Qu'Appelle	28	—38
Regina	23	—45
Saskatoon	18	—35
Souris	20	—32
Swift Current	28	—30
Winnipeg	23	—25
Ontario		
Agincourt	46	—11
Oak Ridges	41	—14
Bancroft	36	—35
Barrie	..	..
Beatrice	39	—35
Bloomfield	41	—12
Brantford	51	— 2
Chapleau	..	..
Chatham	55	3
Clinton	48	— 1
Collingwood	43	—14
Cottam	54	— 1
Georgetown	44	—11
Goderich	52	1
Grimsby	51	— 1
Guelph	45	— 6

STATIONS	FEBRUARY Highest	Lowest
Ontario—cont.		
Haliburton	40	—35
Huntsville	42	—38
Kenora	24	—32
Kinmount	40	—34
Kingston	45	—13
Kitchener	46	— 4
London	52	— 4
Lucknow	48	—10
North Gower	40	—20
Oshawa	..	..
Ottawa	43	—21
Paris	48	— 3
Parry Sound	39	—30
Peterborough	43	—22
Port Arthur	34	—24
Port Dover	45	0
Port Stanley	44	— 2
Queensborough	40	—25
Ronville	40	—39
Southampton	43	— 8
Stonecliffe	..	..
Stoney Creek	50	— 2
Toronto	48	— 7
Uxbridge	40	—18
Wallaceburg	..	..
Welland	56	2
White River	33	—46
Quebec		
Brome	39	—34
Father Point	40	—12
Montreal	42	—15
Quebec	41	—23
Sherbrooke	43	—22
Maritime Provinces		
Charlottetown	40	—22
Chatham	44	—32
Fredericton	46	—35
Halifax	42	—20
Moncton	47	—26
St. John	45	—14
Sussex	44	—37
Sydney	40	—18
Yarmouth	42	2

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries

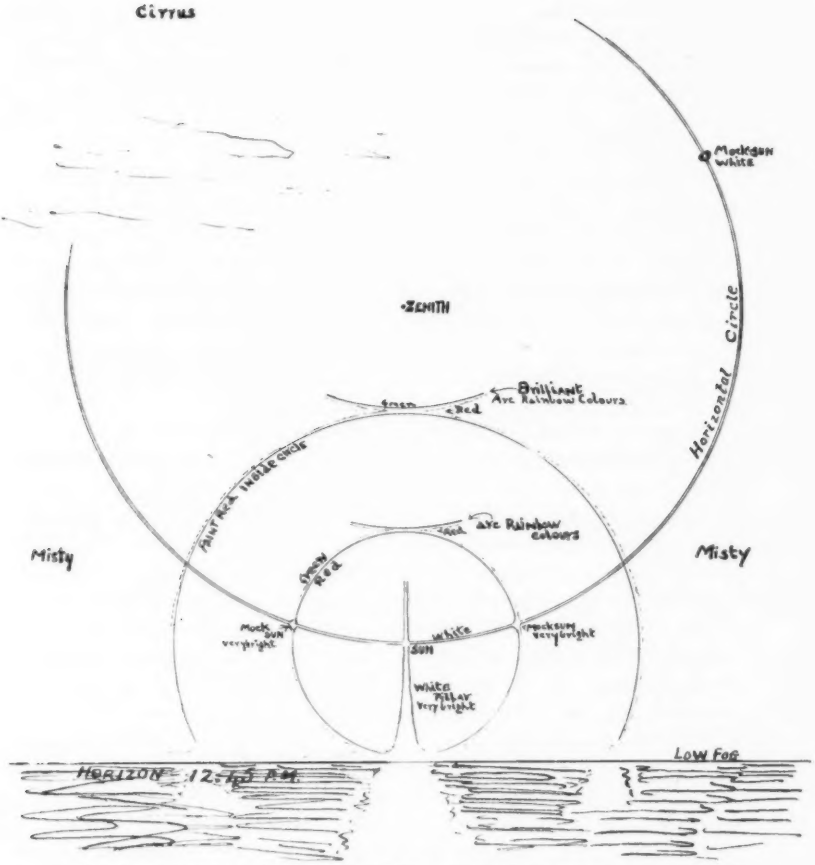
A SOLAR HALO OF UNUSUAL BRILLIANCE, AND OTHER PHENOMENA

Mr. B. S. Wimbush of Garden Plain, Alberta, (Long. 112° W., Lat. 52° N.), under date of February 10th, writes:

Enclosed is a sketch of a solar halo seen to-day for two or three hours. One person who lives on the rural telephone line (several miles of which runs north and south, which is significant as the magnetic lines run the same here) remarked that in the evening of the 9th the telephone receiver crackled very much (with static discharges). There was too much haze and drifting snow and clouds to see any possible aurora; but to-day we get the mock suns and halos.

The inner circle, with parhelia (mock suns), and the horizontal circle (white) passing through the inner circle, were evident. The upper tangent arc was very beautifully coloured, as also were the mock suns and inner circle. The lower tangent arc was also coloured but, like the outer circle, fainter. The upper arc and inner circle were bright; the lower arc and outer circle were fainter. The sun pillar could be traced right to the observer's eye, and was so bright as to hide the horizon, and the ice spicules were white; whereas the ice spicules in line with the parhelia were coloured right up to the eye. The ice spicules flashed light only in these two positions, but as the distance grew greater they multiplied and therefore got very bright over the horizon. The storm had just passed leaving cirrus clouds in the east, northeast and southeast. A low fog of ice crystals extended for about three degrees above the horizon, and the ends of the circles and pillar were very dazzling in this, the brightness extending right along the horizon between the extremes of the outer circle.

Mr. Wimbush also reports a beautiful aurora on the night of February 14th, with the thermometer 9 degrees below zero, Fah. Most of the movement during the display was to the left, especially in the lower band of light. It occurred about 9 p.m. (Mountain



Solar Halo seen by B. S. Wimbush, Garden Plain, Alta. 11 a.m. to 1.30 p.m., February 10, 1922. Outer circle fainter than inner; ends of circles very bright in fog on horizon—Scale, 1 inch = 33°.

time), and was of short duration, being faintly coloured at some times, becoming a white glow about 9.30 p.m.

In coal mines, the roof scales off more in rainy weather than at other times, in the various parts of the mine. As the barometer is usually low at such times, Mr. Wimbush has observed that the

cause of the falling off from the roof is the lessening of the air pressure. He states that he has frequently proved it by a comparison of the figures shown by the barometer. Whenever the mercury falls a quarter of an inch or so, scale falls in the mine.

LECTURE BY DR. KLOTZ IN BROOKLYN, N.Y.

On February 28th, Dr. Klotz, director of the Dominion Observatory, Ottawa, lectured before the Brooklyn Institute of Arts and Science on "Astronomy in Canada". Included in the address was an account of geophysical work,—seismology, gravity and terrestrial magnetism. The lecture was illustrated with lantern slides. There was a large audience and the chairman expressed great surprise at the amount and variety of astronomical work being done in Canada.

AN EXTRAORDINARY FIRE-BALL

A despatch from New York, dated February 19th, 1922, relates that Frank C. Blessing, second officer of the Lamport and Holt liner "Vauban" saw a remarkable fire-ball on the night of February 11th, when the ship was off the coast of Brazil. It was during the first watch and the second officer was on the bridge in charge of the ship. He saw the huge ball rise in the west, describe a low arc ahead of the ship and disappear below the eastern horizon. It appeared as large as the full moon and was surrounded by a flaming halo and reached an altitude of about 10° above the northern horizon. It travelled at great speed and was in sight 3 minutes 20 seconds.

In describing the phenomenon officer Blessing said: "The ball was very fiery and a brilliant red, with a tail and a long fiery trail, which lit up the sea in all directions. The ship, and for a quarter of a mile around, was lit up like day, and the light was so brilliant that it dimmed the lamp in the binnacle and the smoking-room lights, which caused passengers inside to rush on deck to see what was the matter. I was scared at the strange sight, because I thought it had something to do with the end of the world. It was too large for a meteor and came up from the horizon on the west and did not drop from the zenith."

This wonderful meteor was somewhat similar to those seen in

the great display of February 9th, 1913, which was investigated by the present writer, the account being published in this JOURNAL, volume 7, pages 145-215, 1913.

THE GEODETIC SURVEYS OF THE UNITED STATES AND CANADA

The present writer has received the annual report of the Director of the U.S. Coast and Geodetic Survey for the year ending June 30th, 1921, and that of the Superintendent of the Geodetic Survey of Canada for the year ending March 31, 1921. They both contain much interesting information and show how fundamental to our complicated social organization is the work carried on by them.

Director E. Lester Jones, of the U.S. Survey, first points out that his staff is not as efficient as it should be on account of the low salaries paid,—much lower than in some other government offices,—and he urges more generous treatment in order to secure and retain the most competent persons. The work carried on by the Survey is of a varied nature, dealing with geodetic, hydrographic, topographic, and magnetic work and also tide and current observations. These relate not only to the United States proper, but to Alaska, Hawaii, the Philippines, Porto Rico, the Virgin Islands and Panama. The Survey has rendered honourable service to the nation for over one hundred years, and it is to be hoped it will receive the support necessary for its efficient operation.

The Canadian Survey is quite youthful in comparison with the other, the report just issued being only the fourth since the Survey became a distinct separate entity. The map illustrating the progress shows that triangulation is completed over the greater part of old Ontario and Quebec, as well as much of the maritime provinces and British Columbia, but little has been done in the three prairie provinces. There is an immense area still untouched. Some account of an experimental aerial survey of Ottawa is given. Numerous difficulties were experienced and progress made in overcoming them, and it is expected that the airplane will largely influence the future methods of topographical surveying. An accurate survey of the city of London, Ont., has been made.

Besides the maps showing progress of triangulation over the Dominion and at London, there are illustrations of a new dis-

mountable ladder 78 feet high and of various instruments used in the work of the survey. No doubt Mr. Noel Ogilvie, Superintendent of the Survey, Ottawa, will be pleased to send a copy of his report to any who are interested in this work. Indeed it is highly desirable that the Canadian people should become acquainted with the splendid scientific work being done for the advancement of the country.

NEWS FROM THE DOMINION OBSERVATORY

The Dominion Observatory will have five officers in the field this season. The one party composed of Mr. A. H. Miller, gravity specialist; Mr. J. P. Henderson, wireless expert; Mr. A. H. Swinburn, astronomer, who will proceed west from Edmonton by pack train and canoe to Liard on the 60th parallel, to take observations for gravity, longitude and latitude. They will float down the Mackenzie 1,400 miles to near the Arctic Ocean, probably Aklavik and obtain similar data there; thence, ascending the Mackenzie to Great Slave Lake and to Fort Reliance, for similar observations; thence, to Fort Chipewyan on Lake Athabaska where observations of the same nature will again be taken.

There will be two magnetic parties, one in charge of Mr. C. A. French for the Peace River, Athabaska and Slave River area.

The other party will be in charge of Mr. R. G. Madill, which will occupy the Hudson Bay Railway area and later cover the area from Cumberland House northward to and beyond the 60th parallel.

Dr. Otto Klotz, Director of the Dominion Observatory, has been appointed by the Dominion Government, as the delegate and representative of Canada, at the approaching meeting in Rome of the International Astronomical Union.

CORRECTION.

In the last issue (page 118) the name of the book written by Mr. Geo. H. Lepper is given as "From Nebula to Man". It should be "From Nebula to Nebula". I regret the mistake. I believe a book bearing the former title was published in England some years ago, and the slip was made through carrying that name in my mind. Mr. Lepper's address is 1505-1510 Berger Building, Pittsburgh, Pa. C. A. C.

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